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Rate-of-change Analysis Applied to Machine Tool Monitoring and Maintenance Schedules

Current Practice

An existing standard method of manufacturing process control is using statistical analysis on the CMM results measured from parts produced on the machine. If the data highlights that the critical features have drifted out of tolerance maintenance are tasked with investigating this data and correcting the machine accordingly.

The downside to this method is that it measures defects in the manufactured part - if you are producing artefacts with a high capital value, or that are the product of months of sequential processing stages, this is an extremely costly and time-consuming method of defect identification.

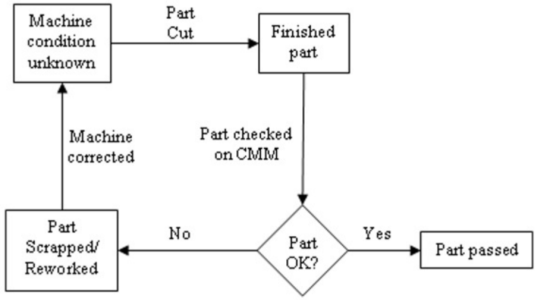

Figure 1: Traditional production cycle

Yearly Service

Service and calibration schedules are often based on the same premise as a car service - one is required every year, so long as there isn't a breakdown in between. This assumption can lead to two situations where:

A) the machine is not being serviced frequently enough
B) the machine is serviced more frequently than required.

Both of these situations lead to costly machine downtime that could be avoided if a condition-based maintenance schedule was available.

Improved Process

By adding a measurement step to the system, prior to the cutting process, problems can be identified before they are turned into defective parts, increasing the efficiency and, ideally, availability of the machine. This reduces the machining process to the cycle shown here in Figure 2.

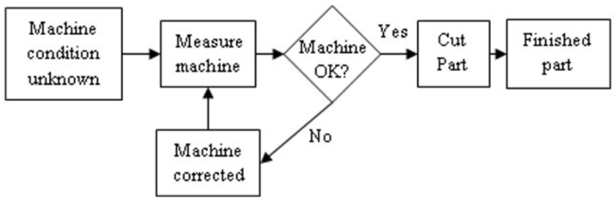

Figure 2: Improved process for reduced defects machining

Rate of Change

If the machine were to be automatically measured against traditional upper and lower absolute tolerances, the errors recoded on the Squareness chart (Figure 3) would pass without comment, although it is obvious, when visually inspected, that something is wrong.

Applying a tolerance to the rate-of-change of the error, however, (as shown in Figure 4) highlights a drastic alteration in the machine's condition. This would allow us to predict that the machine will likely be unable to produce accurate parts before the next set of measurements are taken and the errors discovered.

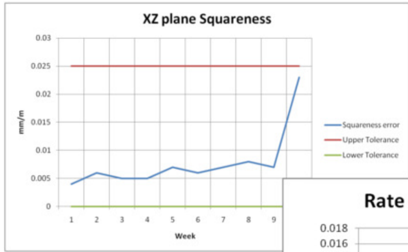

Figure 3: Standard Tolerance. (16mm/m change in the machines alignment in 1 week)

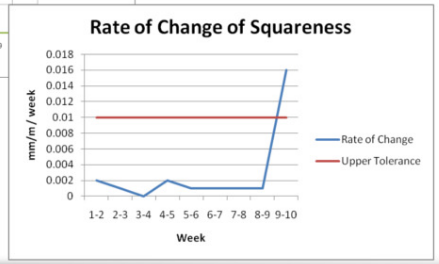

Figure 4: Rate-of-change tolerance

Conclusions

As reducing waste, costs and errors, whilst still delivering on quality have become the main the driving forces in manufacturing industry today, the need to gain greater control over the production processes and machines has risen greatly. It is in this area that preventative condition-based maintenance can have a great impact on machine downtime and part defect numbers.

The process of applying automated rate-of-change tolerancing to regularly recorded metrology data can provide a good early warning system to alert maintenance teams to any rapidly degrading functions. Traditional absolute tolerances that ignore the time domain do not make use of this vital information. Mathematical tools can be used to assist with the optimisation of maintenance schedules, delivery dates and cost projections. In future, by utilising polynomial curve fitting, the accuracy and robustness of predictions can be improved and the interdependency of the various errors investigated.

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